



Food and Crop Research Activities Kennedy Space Center, FL

June 2005

Ray Wheeler

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Gary
Stutte



Neil
Yorio



Howard
Levine

KSC Crop
Research
Team



Oscar
Monje



Yeon-Hye
Kim



Jeff
Richards



Nate
Craighton



Sharon
Edney

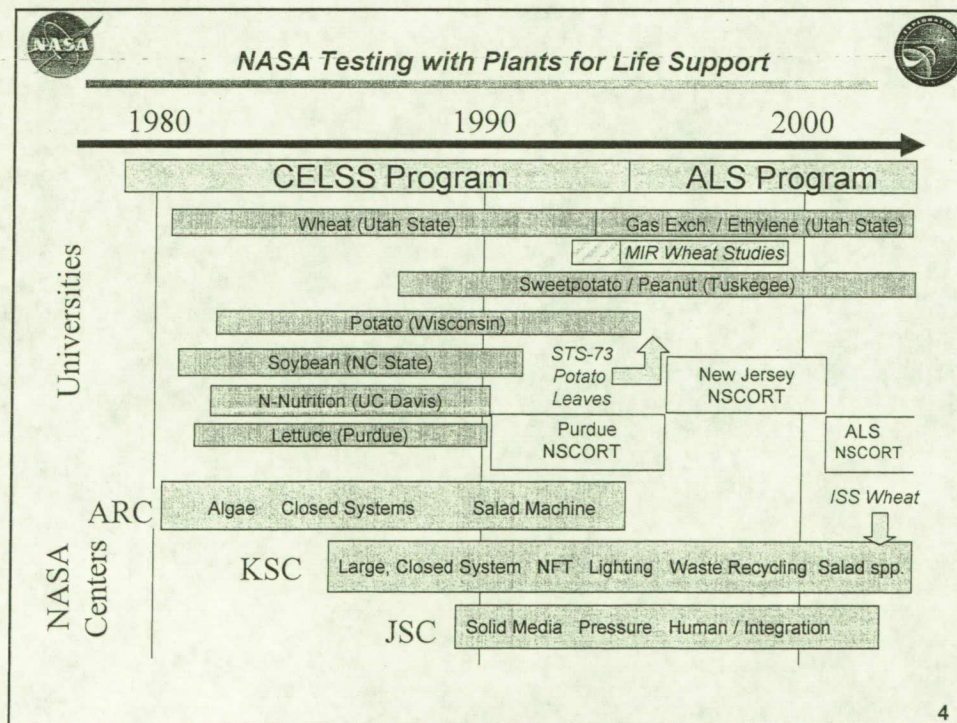
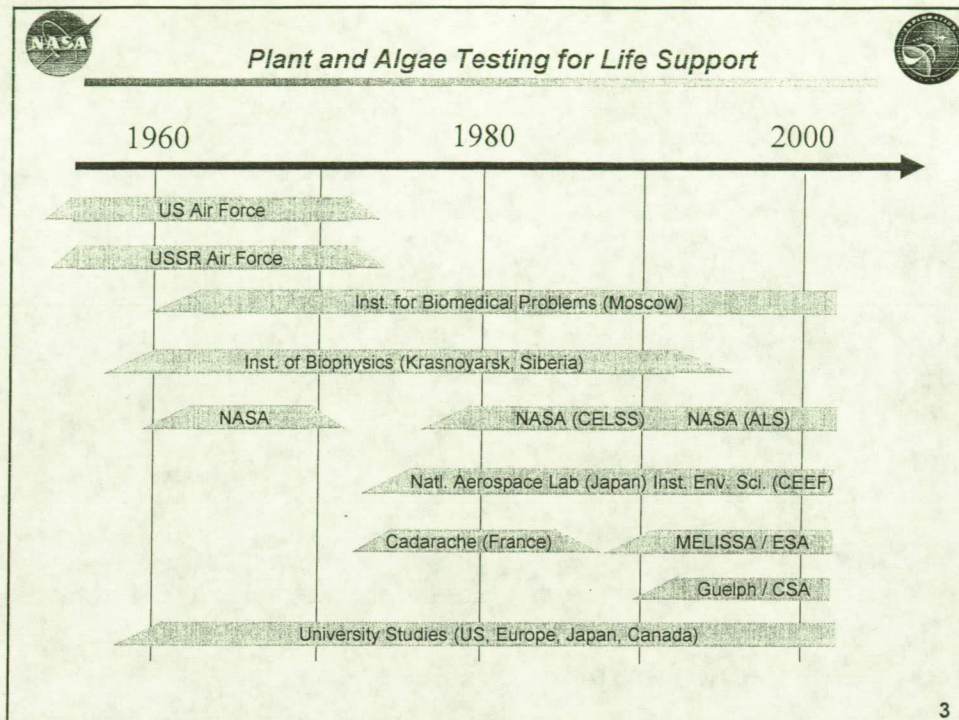


Ray
Wheeler



John
Sauer

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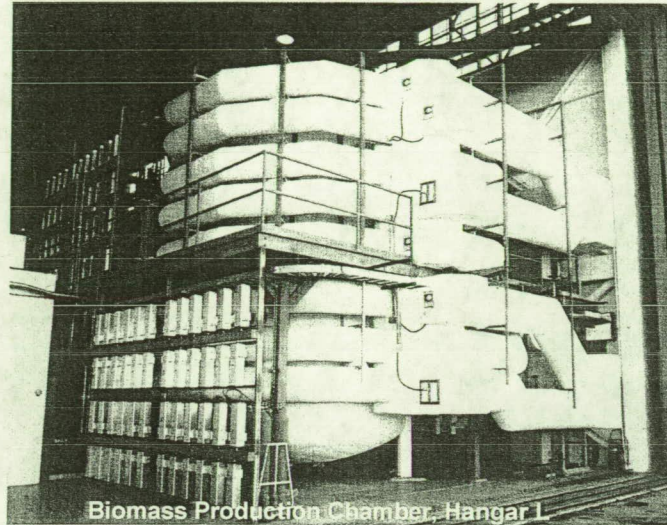




Crop Research at NASA-KSC



⇒ KSC's Crop Research Began in Hangar L ca. 1985
for the CELSS Program

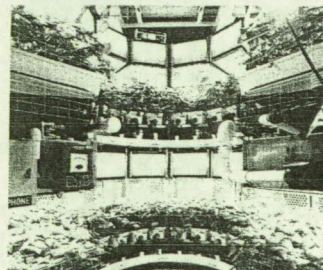
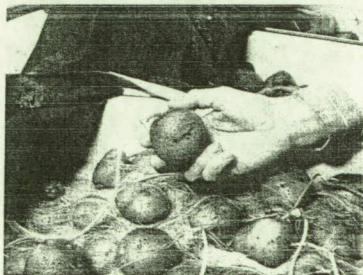
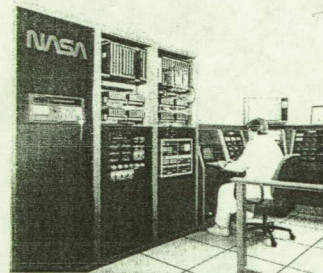


Biomass Production Chamber, Hangar L

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Crop Research at NASA-KSC

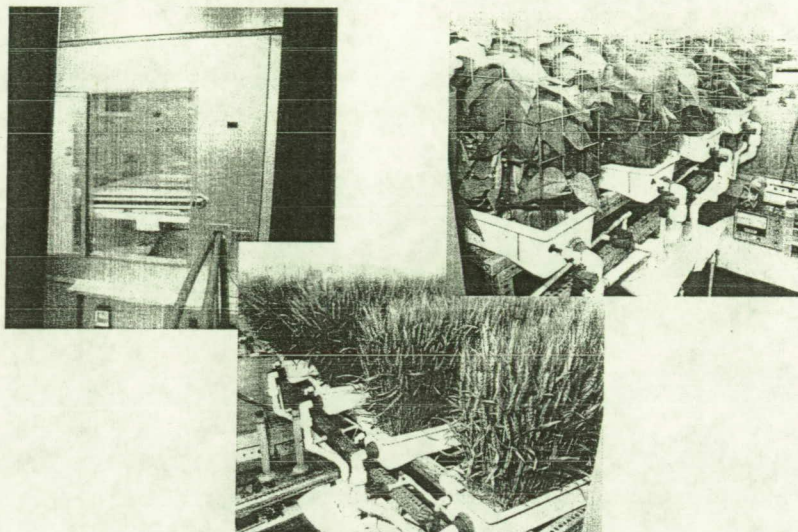


Biomass Production Chamber Studies

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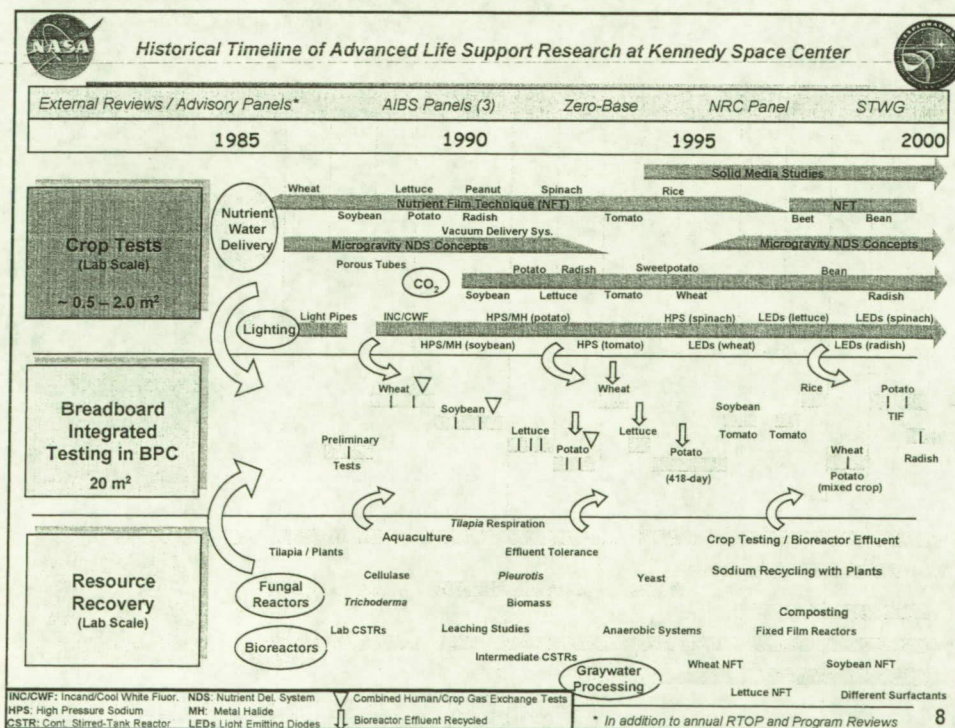


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Crop testing in smaller growth chambers

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Crop Research at NASA-KSC



Current Crop Research Activities:

- **ALS Technology Development Proposal / Technical Task Agreements**
 - Environmental Responses of ALS Crops
 - Cultivar Comparison / Selection
 - Mixed vs. Monoculture
- **NRA Grants**
 - PESTO / ISS Flight Experiment (Gary Stutte)
 - RASTA / VOCA (Gary Stutte)
 - WONDER Flight Experiment (Howard Levine)
- **National Research Council (Hyeon-Hye Kim)**
 - Plant Growth Under LED lighting
- **Graduate Student Research Program**
 - Cornell, Univ. Florida, Univ. Arkansas, Texas Tech.

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TTA Progress:

Environmental Response Tests*

Light: $\mu\text{mol m}^{-2} \text{s}^{-1}$:

150, 300, 450

CO₂ (ppm) :

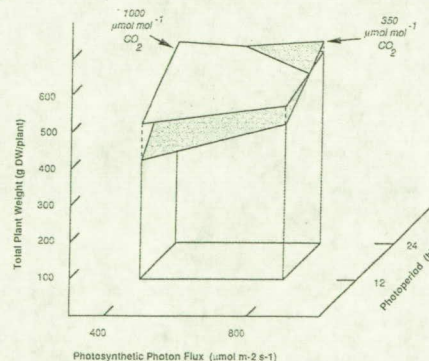
400, 1200, 4000

Temp. (°C) :

22, 25, 28

Target Crops:

- 1) Lettuce, Radish, Onion
- 2) Tomato, Pepper
- 3) Strawberry



* Underlined values indicate conditions typical for open chambers in space cabin

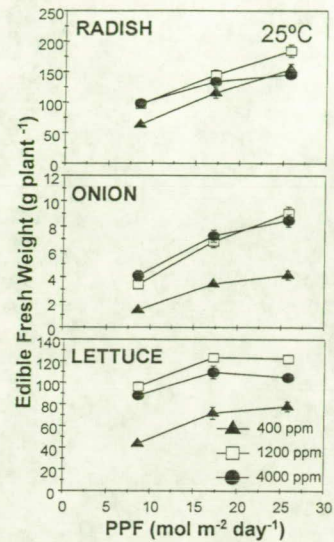
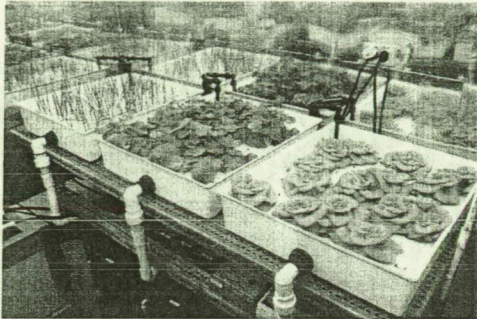
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TTA Progress: Environmental Response Tests



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TTA Progress Cultivar comparisons:

- Lettuce: Waldmanns' Green, Ostinata, Flandria, (Red Sails, Eruption, Outredgeous)
- Onion: Kinka, Kruncho, Choho, Choetsu, Guardsman, Pacific Pearl, Evergreen Hardy White, Deep Purple
- Radish: Cabernet, Fireball, Cherriette, Giant White Glove, Cherry Belle, Sora, Cherry Bomb II, Vintage
- Tomato: MicroTina, Florida Petite, Red Robin
- Pepper: Triton, Hanging Fruit Basket, False Alarm

(underlined indicates the cultivar chosen for further testing)



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TTA Progress: Mixed vs. Monocultures



Mixed Plantings

⇒ No differences
noted to date

- Allelopathy
- Nutrient Competition
- Canopy Competition

Monoculture



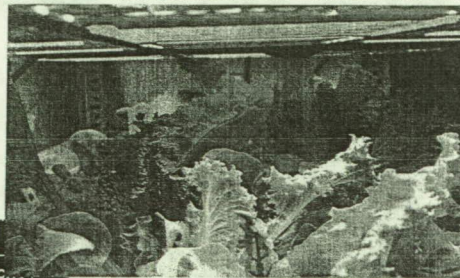
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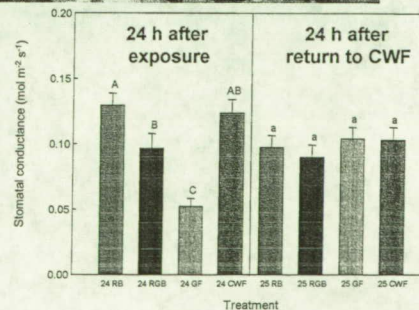
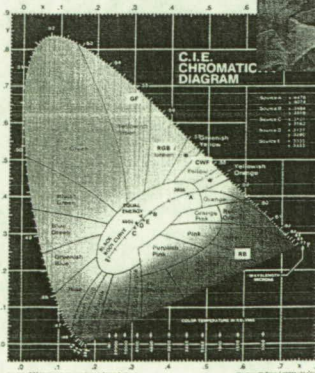
Crop Research at NASA-KSC



LED Lighting Studies



Green Light
for Human
Vision and
Better
Canopy
Penetration



Stomatal Responses to Spectra

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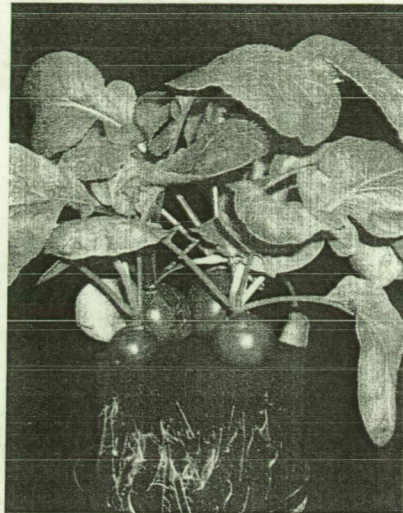
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• RASTA / VOCA Project:

- Team: Gary Stutte (PI), Ignacio Eraso, Sylvia Anderson
- Originally a flight experiment to study effects of volatile organic compounds (VOCs) in closed flight chambers on plant growth (RASTA).
- Transitioned to a Ground – Based project to study volatile organic compounds produced in closed systems, and their effects on plants growth (VOCA)

⇒ Development of a “SMAC” scale for plants



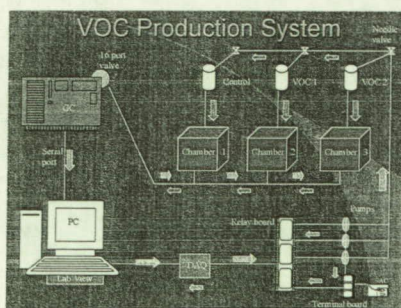
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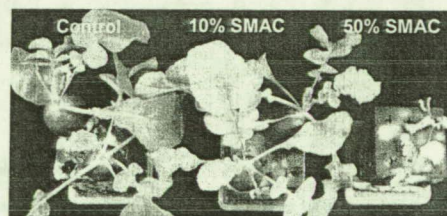
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RASTA / VOCA...Exposure and Collection Chambers

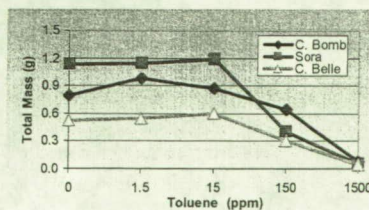


Exposure Chambers

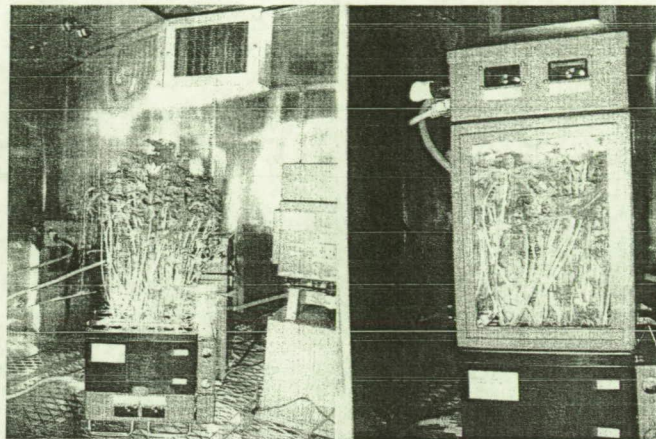


Target VOCs:

Ethylene (10^{-4} SMAC)
Ethanol (10^{-2} SMAC)
Methanol (10^{-1} SMAC)
Toluene (>0 SMAC)
Acetone (>0 SMAC)



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LADA Microbial Risk Assessment
Jay Garland, co-Investigator
(Gail Bingham, Principal Investigator)

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- **Food Analysis and Testing**

- **Proximate Composition**
 - Protein, Fat, CHO, Ash, (Dietary Fiber)
- **Elemental Composition**
- **Antinutrients**
 - Nitrate, Phytic Acid, Oxalic Acid
- **Antioxidants**
 - Vit. E and C, Anthocyanins, Lycopene, Polyphenols
- **Sensory Evaluations**
 - Taste Test Panels at JSC

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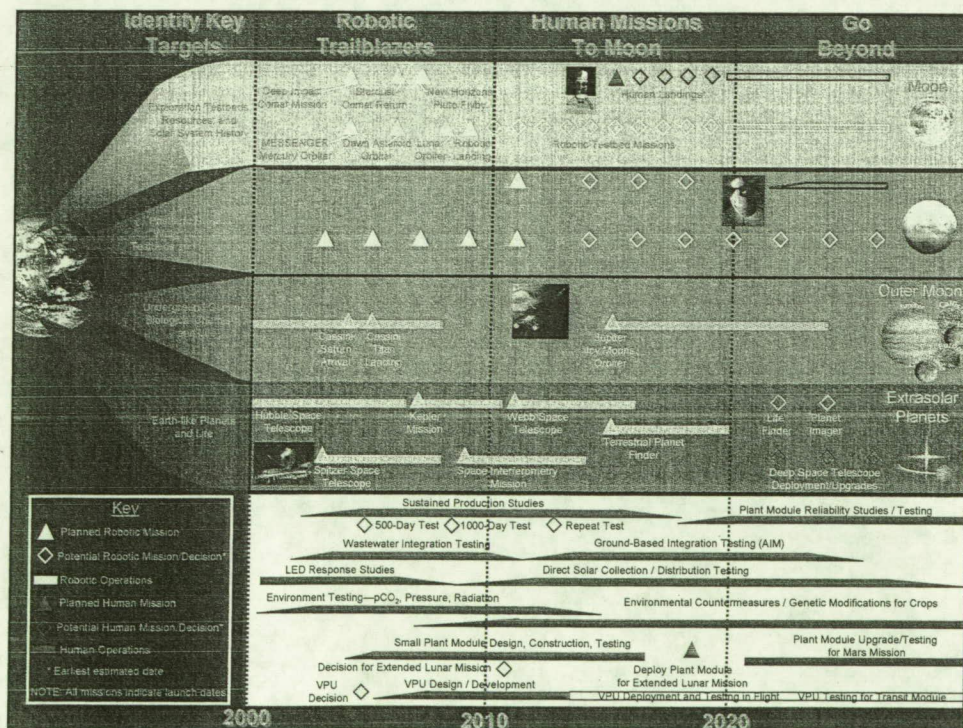


Crop Research at NASA-KSC



- **Crop Production Activities (existing in black and proposed in red)**
 - **Environmental Testing with**
 - Continue Lettuce, Radish, Onion, Tomato, and Pepper
 - Initiate Strawberry Testing
 - Initiate Pressure Response Testing at Univ. of Guelph
 - **Cultivar Selection**
 - Complete strawberry testing
 - Initiate GMO Strategy and Development
 - **Mixed / Monoculture**
 - Continue Lettuce-Onion-Radish / Tomato-Pepper
 - Initiate Long-Duration, Sustained Production Trials
 - **Continue LED Testing**
 - Design and Develop Solar Light Capture / Delivery Systems
 - **Continue Food Quality and Sensory**
 - **Continue VOC Response Testing / Plant SMAC**
 - **Initiate VPU Development**
 - **Support Psychological Response Studies (Human/Plant)**
 - Terrestrial Analogues, e.g., McMurdo Station, Antarctica
 - **Initiate Crop Radiation Response Studies**
 - **Initiate Integrated Crop, Wastewater, Solid Waste Testing**
 - **Initiate Planetary Surface Chamber Design and Development**

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Meetings / Presentations for 2004:

- Intl. Conference on Environmental Systems
- Habitation Society
- Plant Growth Regulator Society of America
- American Society for Horticultural Science
- Intl. Controlled Environment Working Group (NCR-101)
- Int. Society of Horticultural Science
- Agronomy Society of America
- Committee on Space Research (COSPAR)
- International ALS Working Group
- American Society for Gravitational and Space Biology



Crop Publications with KSC Authors for 2004/2005:

1. Berkovich, Yu.A., A.N. Erokhin, S.O. Smolianina, J.J. Prenger, and H.G. Levine. 2004. Development and testing of a cylindrical LED lighting unit for a conveyor-type salad production system. *SAE Tech. Paper* 2004-01-2434.
2. Bucklin, R.A., P.A. Fowler, V.Y. Rygaev, R.M. Wheeler, Y. Mo, L. Hublitz, and E.G. Wilkerson. 2004. Greenhouse design for the Mars environment: Development of a prototype deployable dome. *Acta Horticulturae* 659:127-134.
3. Kim, H.H., G.D. Goins, R.M. Wheeler, and J.C. Sager. 2004. Stomatal of lettuce grown under or exposed to different light qualities. *Annals of Botany* 94:491-497.
4. Kim, H.H., R.M. Wheeler, J.C. Sager, and G.D. Goins. 2004. A comparison of growth and photosynthetic characteristics of lettuce grown under red and blue LEDs with and without supplemental green LEDs. *Acta Horticulturae* 659:467-475.
5. Kim, H.H., R.M. Wheeler, J.C. Sager, N.C. Yorio, and G.D. Goins. 2005. Lighting emitting diodes as an illumination source for plants: A review of research at a Kennedy Space Center. *Habitation* 10(2):71-78.
6. Kim, H.H., R.M. Wheeler, J.C. Sager, and J.H. Norikane. 2005. Photosynthesis of lettuce exposed to different short term light qualities. *Environment Control in Biology* (in press).
7. Krishnamachari, V., L.H. Levine, C. Zhou, and P.W. Pare. 2004. In vitro flavon-3-ol oxidation mediated by a B ring hydroxylation pattern. *Chem. Res. Toxicol.* 17:790-804.
8. Goins, G.D., N.C. Yorio, and R.M. Wheeler. 2004. Influence of nitrogen nutrition management on biomass partitioning and nitrogen use efficiency in hydroponically-grown potato. *J. Amer. Soc. Hort. Sci.* 129:134-140.
9. Norikane, J.H., S.B. Jones, S.L. Steinberg, H.G. Levine, and D. Or. In press. Porous media matrix potential and water content measurements during parabolic flight. *Habitation* 10(2):117-128.
10. Paul, A.L., H.G. Levine, W. McLamb, K. Norwood, G. Stutte, D. Reed and R.J. Ferl. In press. Plant molecular biology in the space station era: utilization of KSC fixation tubes with RNAlater. *Acta Astronautica*.
11. Prenger, J.J., S.L. Steinberg, D. Haddock, J.H. Norikane, and H.G. Levine. 2004. Accuracy of a point source thermal soil moisture sensor for space flight nutrient delivery systems. *SAE Tech. Paper* 2004-01-2446.
12. Prenger, J.J., H.H. Kim, J.T. Richards, O. Monje, H.G. Levine, N. Yorio, G. Stutte, R. Wheeler, and J. Sager. In press. Crop production in an extraterrestrial (controlled-environment, microgravity) environment. *J. Agricultural Meteorol.* 60(5):385-390.
13. Prenger, J.J., S.L. Steinberg, D. Haddock, J.H. Norikane, and H.G. Levine. 2004. Accuracy of a point source thermal soil moisture sensor for space flight nutrient delivery systems. *SAE Tech. Paper* No. 2004-01-2446.
14. Richards, J.T., N.C. Yorio, S.L. Edney, C.E. Yunker, and G.W. Stutte. 2004. Evaluating growth characteristics and total anthocyanin content in three cultivars of red romaine-type lettuce (*Lactuca sativa* L.) in response to three lighting intensities. *Proc. Plant Growth Reg. Soc.* 31: (in press).
15. Richards, J.T., S. Edney, N.C. Yorio, G.W. Stutte, R.M. Wheeler, G.D. Goins, N. Cranston. 2004. Effects of lighting intensity and supplemental CO₂ on yield of potential salad crops for ISS. *SAE Tech. Paper* No. 2004-01-2296.
16. Rutzke, C.J., R.P. Glahn, M.A. Rutzke, R.M. Welch, R.W. Langhans, L.D. Albright, G.F. Combs, Jr., and R.M. Wheeler. 2004. Bioavailability of iron from spinach using an in vitro human caco-2 cell bioassay model. *Habitation* 10(1):7-14.
17. Rygaev, V.Y., P. A. Fowler, R.M. Wheeler, and R.A. Bucklin. 2004. Water cycle and its management for plant habitats at reduced pressures. *Habitation* 10(1):49-69.
18. Schuerger, A.C., G.A. Capelle, J.A. Di Benedetto, C. Mao, C.M. Thal, M.D. Evans, J.T. Richards, T.A. Blank, and E.C. Strykowski. 2004. Comparison of two hyperspectral imaging and two laser-induced fluorescence instruments for the detection of zinc stress and chlorophyll concentration in Bahia grass (*Paspalum notatum* Flugge). *Remote Sensing of Environment* 94:572-588.
19. Stutte, G.W., I. Eraso, S. Anderson, and O. Van Den Ende. 2004. Sensitivity of radish to volatile organic compounds: Toluene, ethanol, and acetone. *Proc. Plant Growth Reg. Soc.* 31: (in press).
20. Stutte, G.W., I. Eraso, and P.A. Fowler. 2004. Effects of common ISS volatile organic compounds on growth of radish. *SAE Tech. Paper* 2004-01-2297.
21. Wheeler, R.M., K.A. Corey, G.M. Volk, C.L. Mackowiak, N.C. Yorio, and J.C. Sager. 2004. Soybean canopy gas exchange rates: Effects of lighting. *Eco-Engineering* 16:209-214.
22. Wheeler, R.M. 2004. Horticulture for Mars. *Acta Horticulturae* 642:201-215.
23. Wheeler, R.M., B.V. Peterson, and G.W. Stutte. 2004. Ethylene production throughout growth and development of plants. *HortScience* 39 (6):5-9.